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# Wallops Flight Center Research and Technology 1980 Annual Report

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DEVELOPMENTS IN AERONAUTICS, ATMOSPHERIC AND  
OCEANOGRAPHIC MEASUREMENTS, RADAR  
APPLICATIONS, AND REMOTE SENSING OF INSECTS  
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## INTRODUCTION

The following paragraphs describe the highlights of the accomplishments during the past year at Wallops Flight Center. Wallops has continued its international leadership in the design and interpretation of data from spaceborne microwave altimeters. An airborne lidar system is continuing to measure surface and volume quantities rapidly and repeatably that are otherwise impossible to obtain using traditional instrumentation.

The sponsoring office and a point of contact is given for each project described.

## AERONAUTICS

Activities at Wallops Flight Center in Aeronautics R&T have several facets. Several projects are directed toward solutions to aviation safety problems. The scope of effort during 1980 includes test and evaluation of an Automated Pilot Advisory System, development of an experimental In-Flight IFR Simulator, evaluation of Heavy Rain Effects on Aircraft Performance and Safety, Ultra-Deep-Stall Spina Recovery, Synthetic Voice Technology, Mid-Air Collision Studies, and VFR Pilot Performance in the Terminal Area. A retrieval system for recoverable rocket payloads has been successfully developed. Several Lighter-Than-Air platform studies are reported here.

### Automated Pilot Advisory System (APAS)

It is anticipated that the growth of aviation in the next decade will occur primarily in general aviation thereby placing greater traffic demands on the uncontrolled airport system. Since Air Traffic Control services are not normally provided at these airports, automated systems are being evaluated as a means of ensuring safe and orderly air traffic flow at high density uncontrolled airports. The National Aeronautics and Space Administration (NASA), in cooperation with the Federal Aviation Administration, has developed an experimental APAS to demonstrate the concept that low cost automated systems can provide airport and air traffic advisories at high density uncontrolled airports.

Testing of the experimental APAS was initially performed at NASA's Wallops Flight Center using NASA test pilots, but in May 1980 the system was moved to Manassas Municipal Airport, Manassas, Virginia. This airport was selected because it is a high-density uncontrolled airport with an estimated 200,000 operations per year, and from June 23 to August 16, 1980, the experimental APAS was operated daily. The APAS performance and the APAS concept were evaluated.

The testing at Manassas was the first attempt to evaluate APAS performance in a high density uncontrolled environment. This test proved that low-cost automated systems can provide airport and air traffic advisory information at high density uncontrolled airports. Shown in Figure 1 is the operational rate during one of the most active days at Manassas. This test showed that APAS operated for five hours at an operational rate exceeding 50 operations per hour with a peak rate of 70 operations. The second objective to the Manassas testing was to obtain pilot evaluations of the APAS concept in the environment in which it is intended to operate. One hundred pilots responded to the questionnaire, and their responses showed that 85 percent had a favorable opinion of the traffic advisory with an even larger majority of the pilots preferring the APAS over the currently used self-announcement procedure.

The research is sponsored by the Office of Aeronautics and Space Technology, and further information may be obtained from J. L. Parks, Jr., NASA Wallops Flight Center.

# OPERATIONAL RATE

JULY 13, 1980

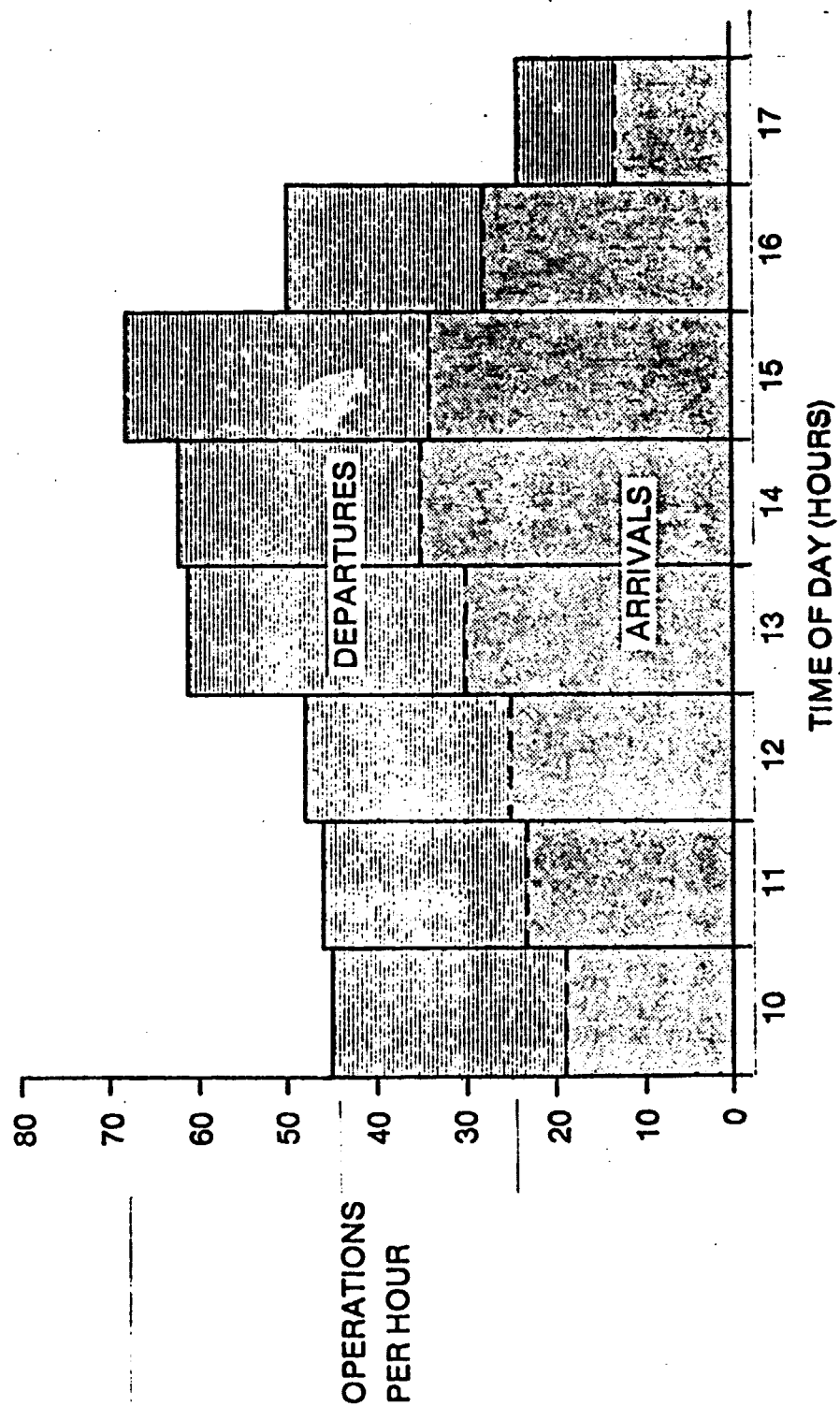


Figure 1

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## In-Flight Instrument Flight Rules (IFR) Procedures Simulator

The design and construction of an experimental simulator has been completed for the purpose of evaluating the training effectiveness, safety and instructor/student pilot acceptance of this training concept. The concept has potential as a cost effective alternative to relieve IFR training airports, to reduce mid-air collisions during IFR flight training, and as an improvement in training effectiveness. In addition to Air Traffic Control voice simulation, various aircraft piloting aids can be represented and presented to the pilot and instructor on simulator driven instruments. Training is to be conducted at a safe altitude away from normal traffic areas. Scenarios provided include elementary procedures such as holding patterns or very high frequency omni-range station (VOR) navigation practice through a full IFR procedures flight.

During the past year the equipment, derived from a commercial table-top simulator, was evaluated for technical feasibility and installed in a Cessna 172 aircraft. Representatives of the Federal Aviation Administration, the Aircraft Owners and Pilot Association, and the General Aviation Manufacturer's Association have been given demonstrations of the equipment. The operational feasibility of this concept is currently being evaluated by the Embry-Riddle Aeronautical University. The final evaluation report by the contractor is due in early 1981.

This research is sponsored by the Director, NASA Wallops Flight Center, and further information may be obtained from J. Brad Aaron, NASA Wallops Flight Center.

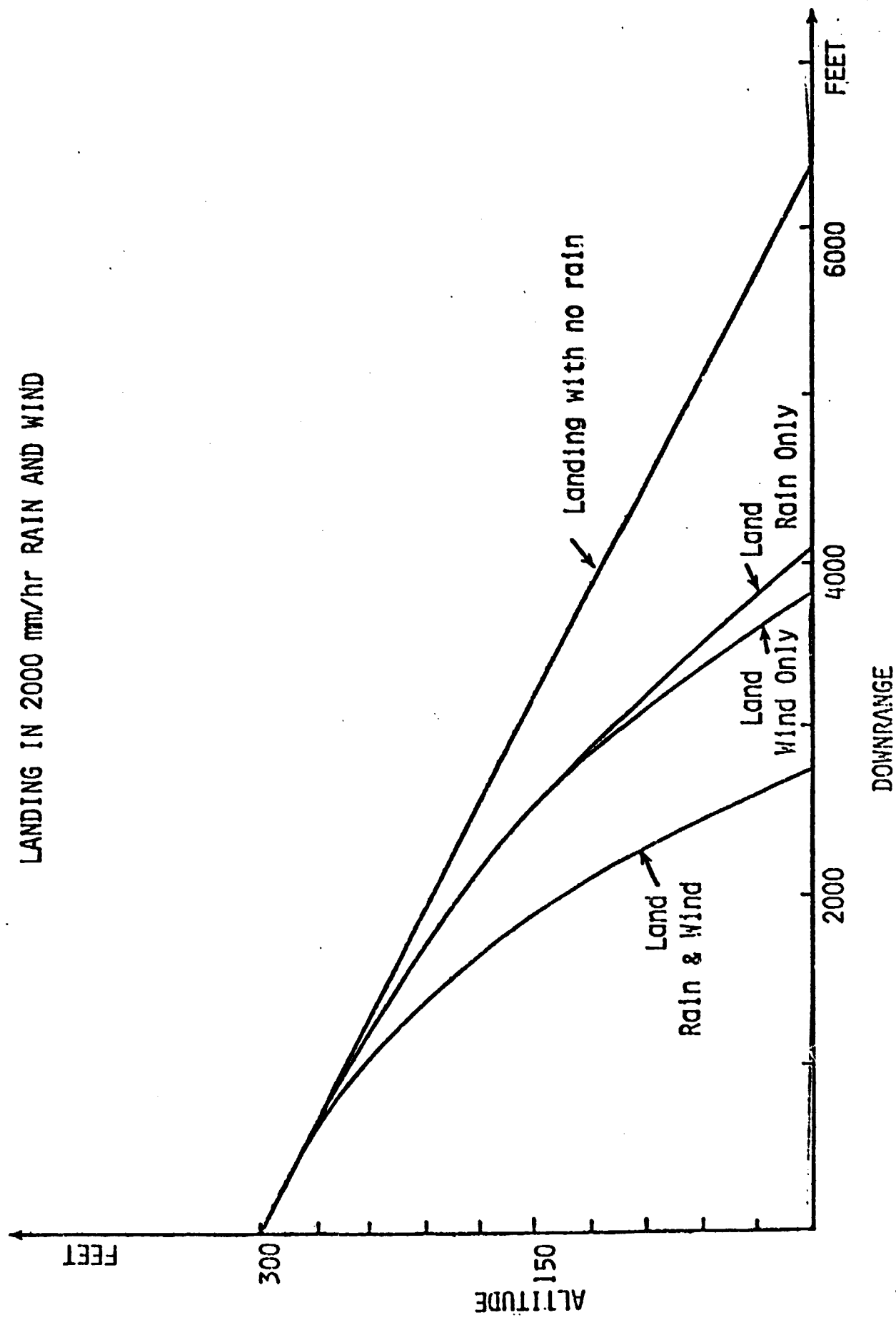
## Heavy Rain Effects on Aircraft Performance and Safety

The crash of an Eastern Airlines Boeing 727 at Kennedy International Airport in June 1975 and an Allegheny Airlines DC-9 at Philadelphia in June 1976 sparked intense interest and study concerning the effects of wind shear on an aircraft during landing. Totally overlooked in these accident investigations was the possible role on the aircraft's aerodynamics due to the heavy rain encountered by each aircraft.

Under a grant with the University of Dayton, an aircraft landing simulation model was developed to evaluate the effects of heavy rain upon aircraft landings. Computer landing simulations using fixed controls with unaccelerated flight in a constant wind field generated a baseline trajectory to a desired landing point. Repeated landing simulations with the same initial conditions but introducing combinations of wind shear and/or heavy rain results in deviations from the landing point. This resulting deviation in the touchdown point represents the severity effect of heavy rain to the landing aircraft. An example is shown in the related figure with the maximum rainfall rate considered. Very heavy rain appears to be an important factor in landings.

The research is sponsored by the Office of Aeronautics and Space Technology, and further information may be obtained from W. E. Nelson, Jr., NASA Wallops Flight Center.

LANDING IN 2000 mm/hr RAIN AND WIND





## High Altitude Powered Platform

In an ongoing effort to support the development of new and improved experiment platforms Wallops Flight Center has in 1980 continued its study effort for a High Altitude Powered Platform (HAPP) Concept. The Platform will provide a station keeping experiment capability to the scientific and application user community for remote sensing, surveillance and communication. It is based on a Lighter-Than-Air (LTA) concept which would be powered by microwave energy transmitted from the ground. In 1980 a study was completed defining the flight microwave receiving system design. Follow-on studies include an LTA Vehicle Definition Study and a Ground Microwave Transmission System Design Study.

The flight microwave study defined the design of a microwave power reception and conversion system for use on a HAPP LTA Platform. The study was focused on the designing and testing of a thin-film printed circuit, microwave rectenna, a combination antenna and rectifier, which was initially concluded to be the best design concept for the LTA HAPP system. Estimated performance based upon laboratory tests is for an output power to mass ratio of 1 kilowatt per kilogram.

This research has been sponsored by the Office of Aeronautics and Space Technology. For further information contact Harvey C. Needleman at Wallops Flight Center.

### Publications

Brown, W. C., "Design Definition of a Microwave Power Reception and Conversion System for Use on a High Altitude Powered Platform," Raytheon Company; NASA CR-156866, June 1980.

## Balloons

As part of its support for the NASA Scientific Balloon Program Wallops Flight Center has initiated an R&D effort into improving the understanding of scientific ballooning. In 1980 two areas were advanced, the first; the thermal modelling of the balloon during all phases of flight; and the second; the development of a gage to measure the state of stress in the balloon film during all phases of flight.

This research has been sponsored by the Office of Space Science and the Office of Space and Terrestrial Applications. For further information contact Harvey C. Needleman at Wallops Flight Center.

## Skyvan Mid-Air Retrieval System (MARS)

Wallops Flight Center has developed a mid-air retrieval system for the retrieval of parachute-born payloads. The retrieval of these payloads permits the gathering of data which cannot be transmitted, such as photographic film, and permits substantial time and money savings through reflight of unique and costly instrumentation.

### System Components and Operation

The MARS consists of (1) a Short Brothers and Harland SC-7 "Skyvan" aircraft, (2) a retrieval winch, (3) rope and hooks, (4) pole mounts, (5) three-section poles, (6) parachute containment trough, and (7) safety equipment. Most of the rope is wound around the winch drum. One end of the rope is led from the drum and is spliced around a hole in the hook. The hook is placed in a retainer at the end of the lowest pole section and the pole is assembled and deployed at a 45 degree angle through the pole mounts at the cabin aft door. The hook is thus positioned about twenty feet below and twenty feet behind the Skyvan. A second hook and pole system can be employed if desired.

The Skyvan pilot executes a retrieval pass by flying above the parachute so that the hook is flown into the parachute canopy. The pole retains the hook long enough to "set" the hook -- thrust the hook through the canopy material with sufficient force to reach, and securely hold, reinforcements in the parachute canopy. The momentum in the parachute and payload then pulls the hook free from the pole, unwinds rope from the drum, and spins the drum. After the drum spins a number of times, a mechanical brake is automatically applied to the drum, and it is braked to a halt. The rope payout and subsequent drum braking accelerates the parachute and payload up to the Skyvan flight speed of 80 knots, and ultimately places them in tow 70 meters (200 feet) behind the Skyvan. A crewman then activates an electric motor on the winch which winds the rope, parachute, and payload into the cabin. The rope and parachute are guided through a trough inside the Skyvan cabin. The trough prevents the rope or parachute from injuring personnel or damaging equipment while they are in motion in the cabin.

### Results

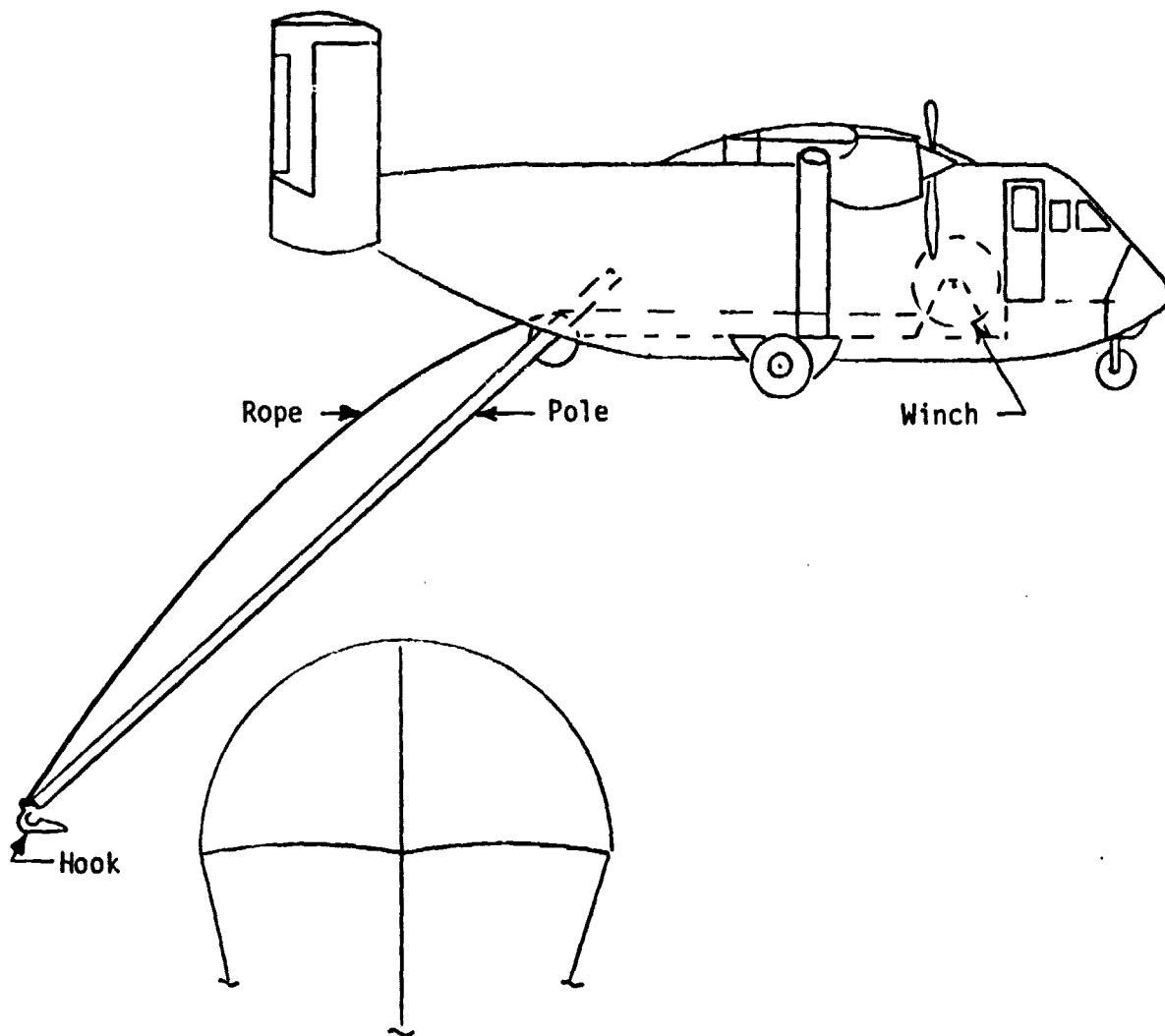
Wallops attempted twenty mid-air retrievals between September 1979, and October 1980, and all were successful. Seventeen retrievals were of sounding rocket payloads, and three of the retrievals were of Navy F-18 spin parachutes. The seventeen sounding rocket payloads consisted of: (a) five Wallops Nike-Orion payloads which measured ozone for the International Ozone Rocketsonde Inter-comparison; (b) five University of Michigan Astrobee-D and Orion payloads which measured nitrous oxide; (c) three Pennsylvania State and U.S. Army Astrobee-D and Super Arcas payloads which measured the earth's electric field and ion concentrations, and (d) four Goddard Space Flight Center Super Arcas payloads which measured ozone during darkness. The F-18 spin parachute retrievals permitted post-deployment examination of these parachutes after their flight testing, when otherwise they would have been lost in the Chesapeake Bay.

These flight operations have returned over \$570,000 of reusable sounding rocket hardware. Payloads weighing between 3 and 100 kg (6 and 225 pounds) have been retrieved. Three payloads launched within twenty minutes of one another were retrieved in a single Skyvan flight. Five payloads have been retrieved in a single day.

#### Development of Further Capabilities

The Skyvan MARS is still in the development process. Hardware is available which can increase its recovery weight capacity from the present 136 kg (300 lb) limit up to 455 kg (1,000 lb). Hardware is being developed to recover ultra-light payloads in the two-to-five-pound range. Hardware and procedures are being planned to permit payload recoveries at international sites such as Peru.

The Skyvan MARS was documented in a paper titled "Evaluation and Operation of Wallops Flight Center Mid-Air Retrieval System on a Skyvan Aircraft," by Douglas C. Young (AIAA 76435260). Further information on this technology may be obtained from Mr. Young at NASA Wallops Flight Center.



## AGRICULTURE

Activities at Wallops Flight Center are related to the application of NASA technology to agricultural problems. Efforts at this Center are conducted under the Office of Space and Terrestrial Applications, Civil Systems Program.

### Agro-Environmental System

The Agro-Environmental System is a cooperative effort between NASA and Virginia Polytechnic Institute and State University (VPI&SU) to provide crop management advisory information to Virginia farmers. In FY 1980 the system operated with seven remote stations (five automatic, two manual) providing environmental data for crop management models. Two additional remote sites have been contracted for and should be erected in the near future. The Cecospora Leaf Spot model was tested for the second year with excellent results. Approximately three years of testing are required before the output advisories can be rated other than experimental. A hydrological model concerned with supplemental crop irrigation was tested for the first time, and several other models are being prepared for testing. The precipitation estimation program utilizing satellite data is being tested during this season; as it proves itself and becomes part of this system, the accuracy and value of the information will increase. A study analysis is underway to determine the proper method in which to integrate the system into the structural organization of VPI and the state of Virginia. A successful workshop was held at VPI&SU in January 1980 at which time the system was demonstrated and explained to the state agricultural community. Copies of the proceedings are available.

This research is sponsored by the Office of Space and Terrestrial Applications. For further information contact J. Holland Scott at Wallops Flight Center.

## ATMOSPHERIC MEASUREMENTS

Much of the Wallops effort in atmospheric measurements is concerned with acquiring data of the highest quality for comparison with spacecraft acquired data measuring the same quantities. The measurement of ozone has been studied in especially great detail using both ground based instrumentation as well as balloon and rocketsondes for in situ measurements.

New systems have also been developed for measuring ozone and nitric oxide.

In-depth comparisons of in situ and spacecraft measurements of temperature profiles have also been accomplished.

### Atmospheric Chemistry

One of the fundamental objectives of NASA's Environmental Observations Division is to develop an understanding of the distributions, sources, and sinks of trace species in the atmosphere. Wallops Flight Center carried out two research efforts in atmospheric chemistry during 1980 to help meet this goal. First, a laboratory study of the accuracy and precision of balloon-borne ozone-sondes used to measure stratospheric ozone was conducted. This study quantitatively demonstrated good overall performance by the ozonesonde, but suggested the need for revisions in corrections applied to high-altitude data to compensate for decreased efficiency of the sampling pump at low pressures.

The second effort involved the NASA funded project RAVE (Research on Atmospheric Volcanic Emissions), a joint NASA/University study of volcanic emissions and their potential effects on the stratosphere. The Wallops contributions to this project included the development of aircraft systems for measuring atmospheric ozone and nitric oxide. These systems were recently used to sample the emission plume from Mt. St. Helens.

This research has been sponsored by the Office of Space and Terrestrial Applications. Further information on these efforts may be obtained from Dr. A. L. Torres, NASA Wallops Flight Center.

### Total Ozone Photometer Intercomparison

An intercomparison of five ground-based spectrophotometers and photometers capable of optically determining the total ozone amount in the atmosphere was conducted during the past year. The recognized instrument for this measurement, the Dobson spectrophotometer, was used as the standard for comparison. It is a heavy pulley device that is not portable, is expensive to maintain, and which requires manual operation. While modern technology should be capable of producing a sensor comparable in quality to the Dobson that does not suffer these drawbacks, the other instruments in the intercomparison, candidates for this role, were all found to suffer deficiencies of varying severity. Because the Dobson measurements are required for the validation of both satellite, rocket, and balloon ozone profile instruments, either these deficiencies must be corrected or another instrument must be developed.

This research has been sponsored by the Office of Space and Terrestrial Applications. For further information contact Chester L. Parsons at NASA Wallops Flight Center.

## Meteorological Measurements Comparison

Comparisons of conventional in situ meteorological measurements with remote sensors on the Operational Environmental Satellite (TIROS-N and NOAA-6) reveal that large differences can exist in the temperature data. These differences often exceed the desired precision recommended by the scientific community and have caused concern as to their source. During the past year Wallops effort: have concentrated on determining the precision of the in situ devices using extremely detailed methods of analysis. A report, presented to the International Symposium on Middle Atmosphere Dynamics and Transport, held in late July 1980 at the University of Illinois, covered the reliability and precision of the standard U.S. meteorological rocketsonde. This instrument, while inexpensive provides temperature measurements with a precision of 1°C or better to 55 Km. This precision is progressively worse above this altitude, and, while the reason has been hypothesized as due to inadequate sensor correction values, additional testing at these altitudes is desirable. During FY80 ten unique comparisons between satellite overpass measurements and multiple balloon and rocket measurements were conducted. Preliminary indications point to time and space differences between the measurements, as well as a variable atmosphere, as the suspected reason for the observed differences. This study is being conducted only at Wallops Flight Center, a facility located at mid-latitude. Evidence exists, (e.g., from wintertime measurements from Thule, Greenland and more recently in measurements made from Northern Norway) that such measurements should be repeated for different latitudes.

Future effort must be directed at space-time variability during different seasons, different meteorological events, and from different latitudes.

This research is sponsored by the Office of Space and Terrestrial Applications; for further information contact Francis J. Schmidlin.

## OCEANOGRAPHIC MEASUREMENTS

Both visible light and microwaves have been used during the past year at Wallops as probes for remotely measuring ocean parameters. A microwave altimeter can provide a surprising amount of information about the dynamic surface of the ocean. A lidar can provide much information about the water itself. Past successes have been described in previous R&T reports. Here we describe the current state of research in these areas.

### Airborne Lidar System

The aircraft mounted lidar system has the capability to measure both water depth and the intensity of the wavelengths returned from the ocean. This latter mode has been proven successful for measuring chlorophyll content of the water; this is a parameter that can be related to the productivity of the area. Not only chlorophyll may be maintained but also certain organic pigments can be measured that are related to the productivity of the body of water. At the same time the clarity of the water can be determined through a measure of the fluorescent-like return of the water itself (the Raman effect). The figure shows some contour plots for these parameters taken during one day as part of an international remote sensing maritime experiment designated MARSEN. The area is the North Sea.

This research is being sponsored by the Office of Space and Terrestrial Applications. For future information contact Dr. Frank Hoge at Wallops Flight Center.

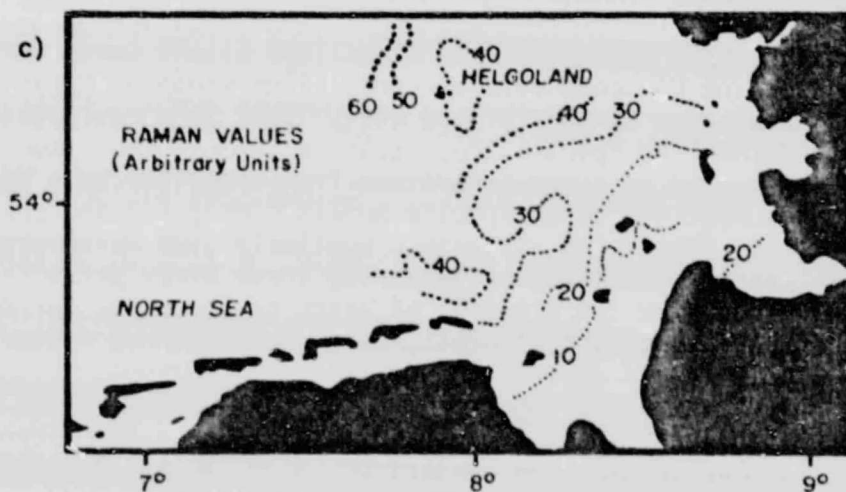
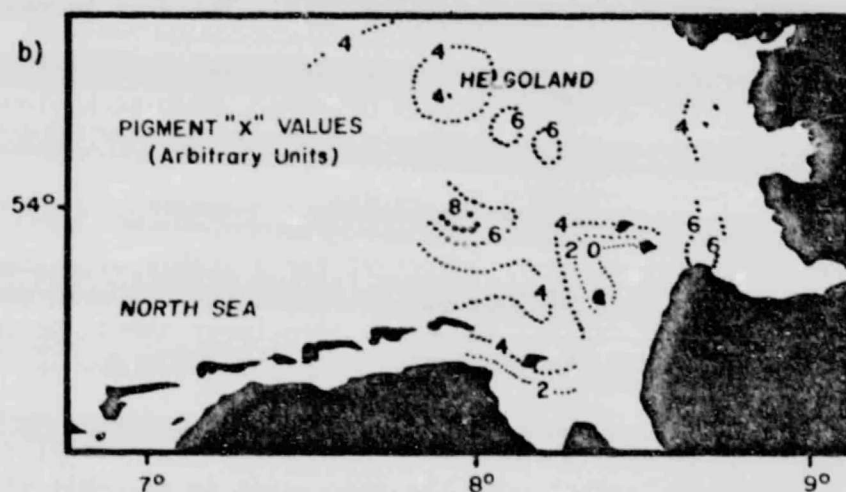
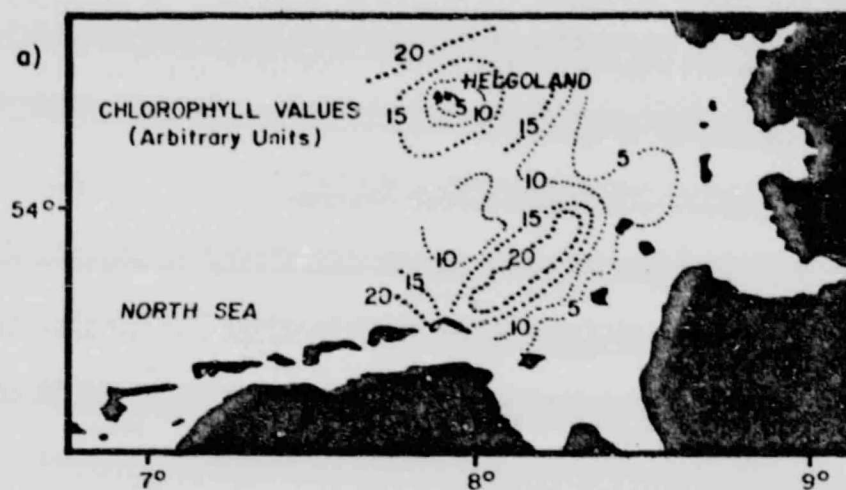
### Ocean Wave Spectra

The measurement of ocean waves is important for a number of reasons. Ships are much safer and use less fuel if they can be routed through calm seas; expensive and hard to replace coastal and ocean structures should be designed for the roughest seas that occur in the area.

For applications such as these a second need becomes apparent; a remote measurement of the waves is called for. A technique for measurement from space becomes especially valuable because once the spacecraft is in orbit virtually any area can be monitored.

The analyses that have been performed at Wallops Flight Center have increased our understanding of ocean wave spectra. (The study of ocean waves is at a time somewhat analogous to that of the early light spectroscopists who were trying to understand the line spectra they recorded through their spectrometers.) Most importantly, by measuring ocean parameters from space the wave spectra can be derived; no longer must the ocean spectra models simply fit the spectral measurements. That is, spaceborne altimeters routinely give wave height information, and it now appears feasible, by measuring these ocean parameters, to obtain the spectra including the grouping of waves so important for damage assessment. By appropriate choice of orbit, this could then be accomplished reliably and repeatedly in any part of the world.

This research is being sponsored by the Office of Space and Terrestrial Applications; for further information contact Dr. N. E. Huang at Wallops Flight Center.



Contour Plots from Lidar Measurements



## RADAR APPLICATIONS

Wallops Flight Center has established itself as a leader in the applications of microwave technology. Spaceborne microwave altimeters have proven themselves to be excellent sources of information about the earth's surface (and by extrapolation should prove to be relatively inexpensive, reliable and efficient instruments for exploring the surface of other planetary bodies). New information obtainable from a spaceborne altimeter is reported in the Oceanographic Measurements Section of this report. Here we describe advances in the altimeter itself that will allow the data to be analyzed more easily and with even greater confidence. A novel application of ground based radar is also presented in which the extreme sensitivity of the instrument is used to study insects in flight.

### Multibeam Altimeter Concept Is Advanced

Wallops Flight Center and The Johns Hopkins Applied Physics Laboratory personnel have made significant progress on a multibeam altimeter system. The concept was proposed several years ago as a means of improving the coverage of altimeter satellite systems. Because the single satellite has a coverage limitation that often is inadequate to map the variation in ocean currents and other dynamic features, a three beam system has been proposed as shown in Figure 1.

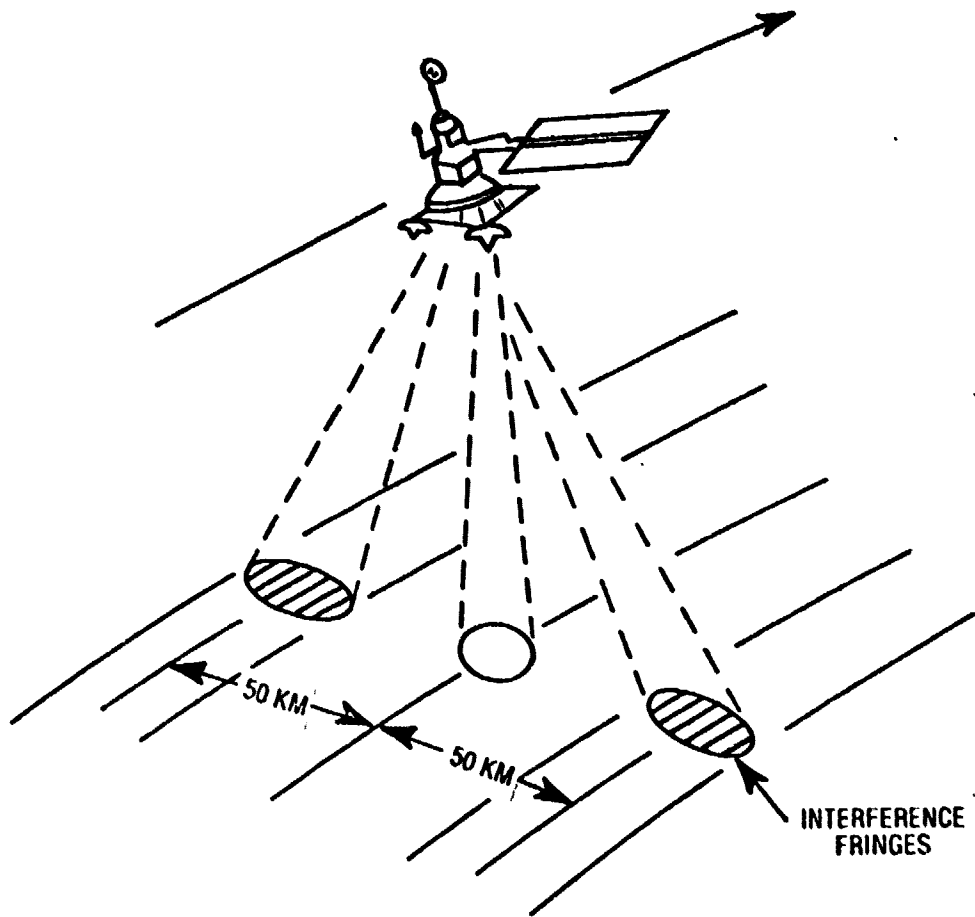
The multibeam altimeter uses a two-antenna interferometer to accomplish with a simpler structure the effect of a large antenna (Figure 1). A pair of small dishes with offset feeds are deployed across track and fed with the proper phase to produce several lobes of an interferometer pattern at the desired point off-nadir. In the time domain each interferometer lobe produces a return like that from the large antenna, allowing the radar to obtain precision off-nadir altimetry by tracking the central interferometer lobe.

This year the concept was further analyzed and simulated to determine if the design parameters were within the state-of-the-art and to evaluate the expected performance characteristics. As a result many factors that could limit the systems accuracy were studied and resolved. An area of particular concern was the variation of tracking bias with system parameters. The effect of significant waveheights was shown to be less than 1 cm rms for waveheights from 0 to 20 meters.

The effect of satellite roll (rotation in the across-track plane) on the tracking bias was greater. Roll causes a large and opposite variation in the two altitudes measured over the swaths on opposite sides of the spacecraft. These two measurements therefore give an excellent measurement of roll. The tracking bias shift is shown to be less than 10 cm for a roll angle of 0.2 degrees. This roll can be easily measured by the altimeter (the apparent altitude shift is  $\pm 200$  m) and the bias variation calibrated out.

The effect of roll rate on the measurement capability of the instrument is also a factor. This effect is critical, a 0.4 arc second roll causes a 10 cm shift in measured altitude. The spectral nature of the roll effect must be kept from masking the sea level information of interest. Crossing tracks appear to provide a method to help remove this effect.

Antenna patterns, echo shapes, and tracking algorithms were also analyzed. The analysis results indicate that the multibeam altimeter can provide wide swath width measurements with precision and accuracy adequate for ocean current mapping.



Multibeam Altimeter

## Remote Sensing of Insects Using Radar

Wallops presently has a technology transfer program with the United States Department of Agriculture to develop specifications for a second generation radar that will be used to monitor the flight activities of insects. Mr. Charles Vaughn at Wallops directs the NASA effort, while Mr. Wayne Wolf at the Southern Grain Insects Research Laboratory in Tifton, Georgia has USDA responsibility. The first generation system is being developed by Wallops in conjunction with The Johns Hopkins Applied Physics Laboratory (APL). A data acquisition and processing subsystem for radars has been designed and fabricated by APL and partially tested at Wallops using the Q-6 and Spandar radars. Central to this subsystem are a 100 MHz Gould 8100 waveform recorder, a logic box for target threshold detection, and an HP9845T with a 9-track tape deck for bulk data storage. The computer performs the following functions: real-time bookkeeping of target signal strength for multiple target surveillance situations; arranges time histories of signal strength of individual targets and performs selectable processing functions such as Fourier analysis and probability density; records target position vectors and provides capability for real-time velocity computation for selected targets of interest; computes target densities as a function of spatial position and time; and, displays these parameters for real-time observer decisions.

The data acquisition system fabrication phase of the program is nearly complete. From July 14 through 24, 1980, NASA, the USDA, and The Johns Hopkins Applied Physics Laboratory (APL) (under contract to NASA) participated in a joint experiment to:

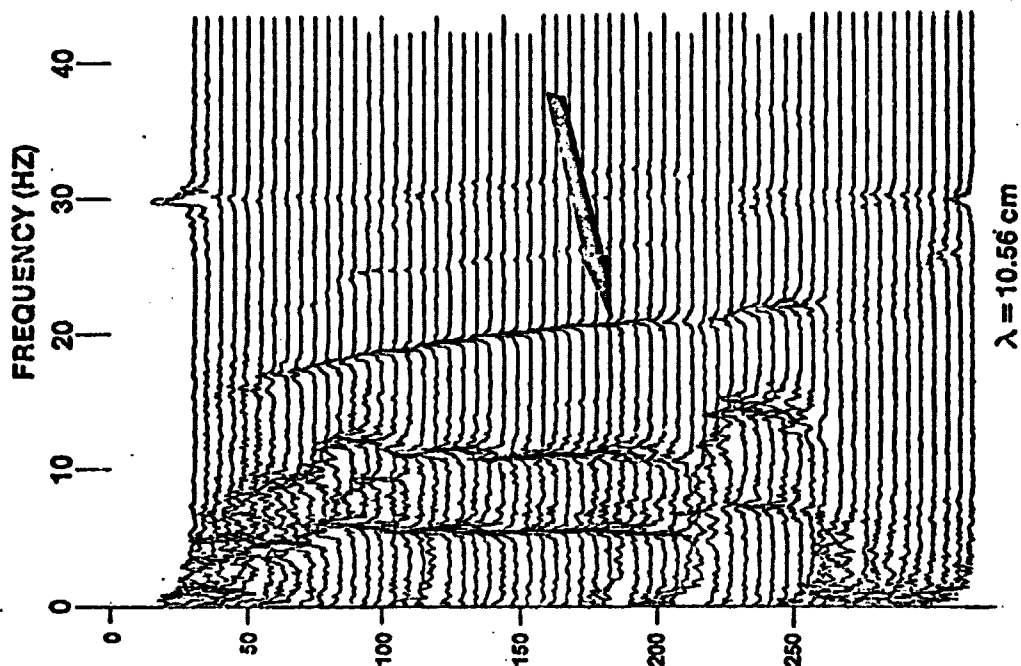
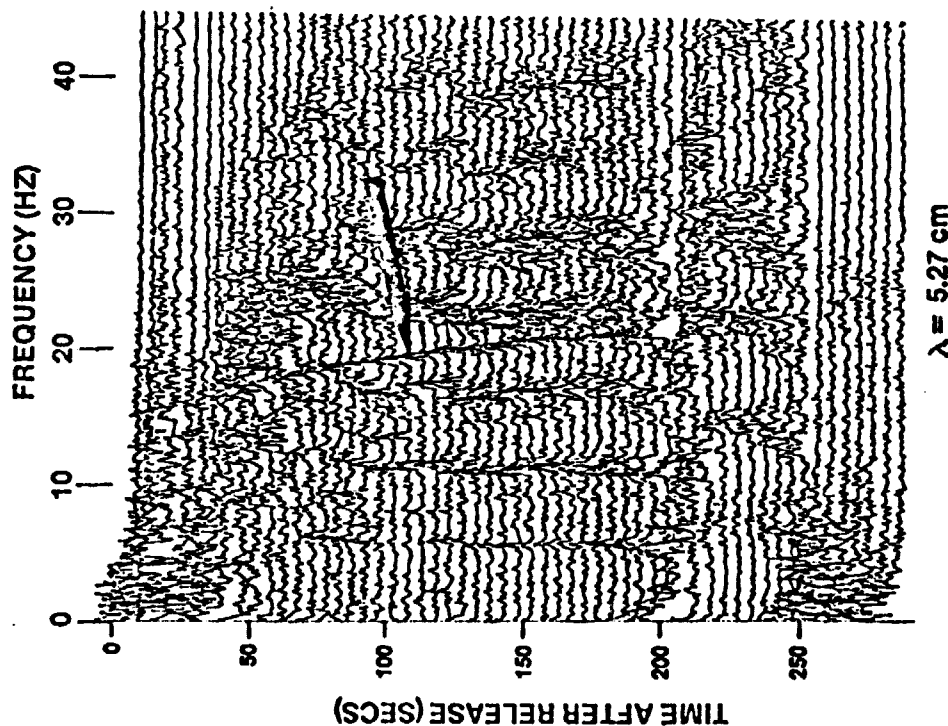
1. test portions of the radar data acquisition system APL is fabricating for NASA; and,
2. acquire time histories of dual frequency radar cross-section measurements on the fall armyworm (*Spodoptera frugiperda*), corn earworm (*Heliothis zea*), and tobacco hornworm (*Manduca sexta*).

### Results

For the five days in which good tracking was achieved by both Spandar and Q-6 radars, a total of slightly more than 350 minutes of data was recorded from each radar. The included figure shows a typical analyzed data product from a single track. This figure shows the evolution of the Fourier spectrum of the energy backscattered from the insect and received by the radar. Each line in one of the two displays was produced from eight seconds of tracking data. Not only does the wingbeating of the insect clearly show, but also another component at 6 Hz (along with many harmonics or overtones), that represents some previously unknown physical behavior of the insect. Such information is useful not only for radar system designers, but also for entomologists who until now have been unable to observe a free flying insect for an extended period of time.

This research has been sponsored by the Office of Space and Terrestrial Applications.

TOBACCO HORNWORM (*Manduca sexta*). Stacked time histories of the Fourier spectra of logarithmic radar cross-section at two radar wavelengths. The arrows show the frequency component associated with wingbeating of the moth. The frequency drift is due to the cold blooded moth warming from exercise after being released at a relatively cool temperature. The 6 Hz component probably originates from a different and presently unknown mode of oscillation of the insects body. Many harmonics of these two fundamental frequencies are also present.



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